HUDSON BAY OPTICS

A synthesis of current knowledge with a view towards the future

Pierre Larouche, Institut Maurice-Lamontagne

Pêches et Océans Canada
Fisheries and Oceans Canada

Introduction

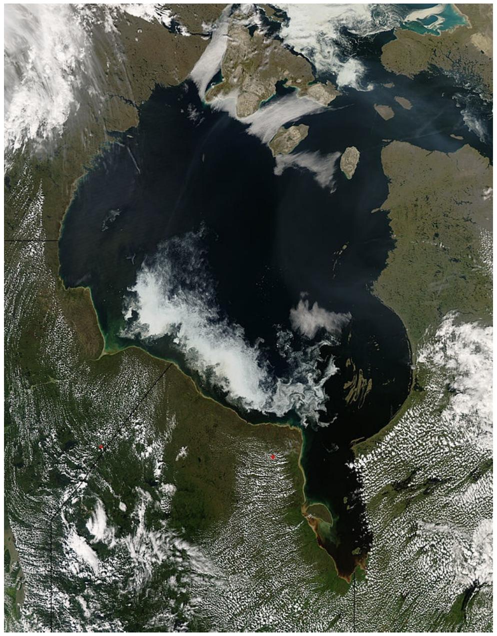
- Already demonstrated that Hudson Bay is evolving (less ice, higher SST)
- Hudson Bay hosts higher trophic level mammals (polar bears, belugas, etc)
- The food chain is dependent on primary production
- Must find ways to evaluate biological impact of climate change

Why study optics ?

- **Well calibrated** remote sensing products can provide information about phytoplankton (biomass, production, functional types) and carbon cycle :
  - Spatial patterns
  - Seasonal evolution
  - Medium-term evolution
  - Relationships with other environmental parameters (ice, SST, freshwater plumes, suspended matter)

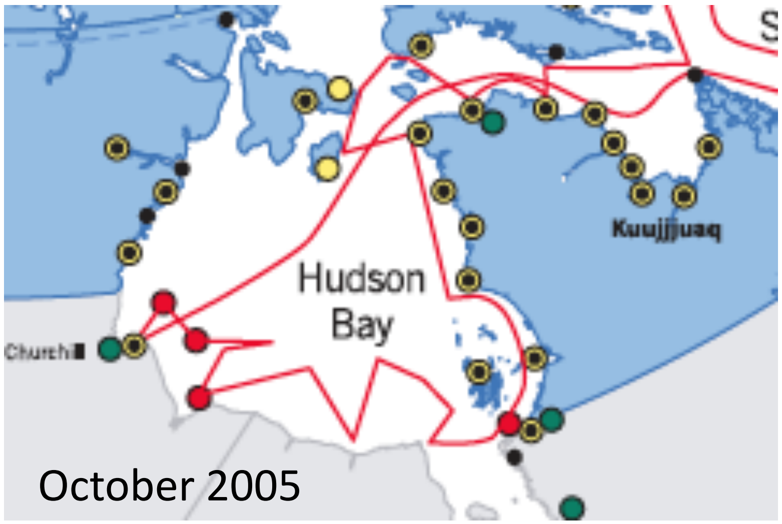
Problems with coastal waters

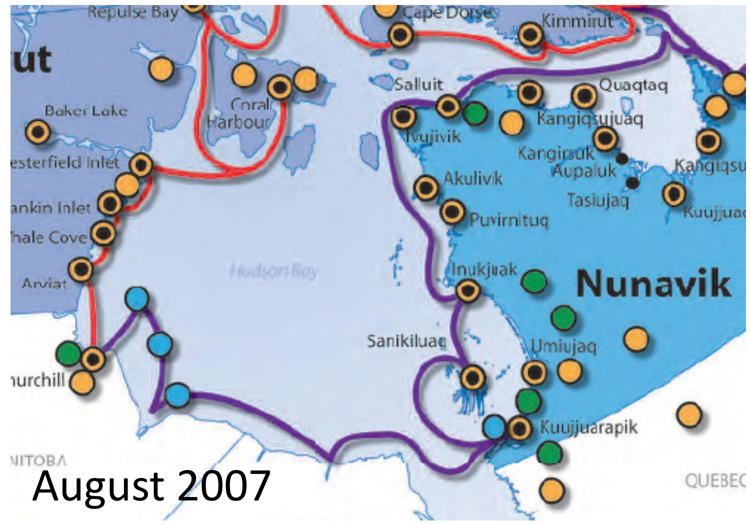
- Remote sensing of phytoplankton is dependent on accurate knowledge of inherent optical properties as:
  - RRS = fct $[b_b / (a+b_b)]$
- In complex coastal waters, competition between water color parameters (inorganic matter, phytoplankton, dissolved matter) for light absorption makes the evaluation of phytoplankton difficult.
- Due to the large freshwater inputs, Hudson Bay is considered as an estuary rather than a sea.
- Relationships found for other coastal areas cannot readily be applied in other areas as specific absorption properties maybe different.

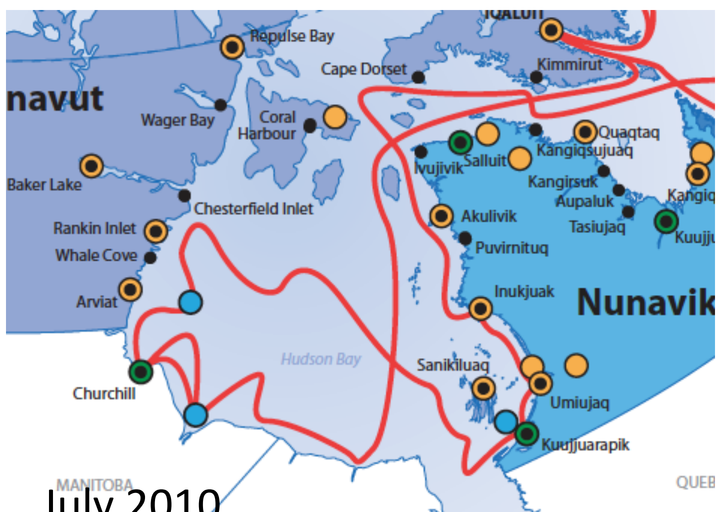


Source of knowledge

(relatively large spatial coverage)







Fall light absorption budget (443 nm)

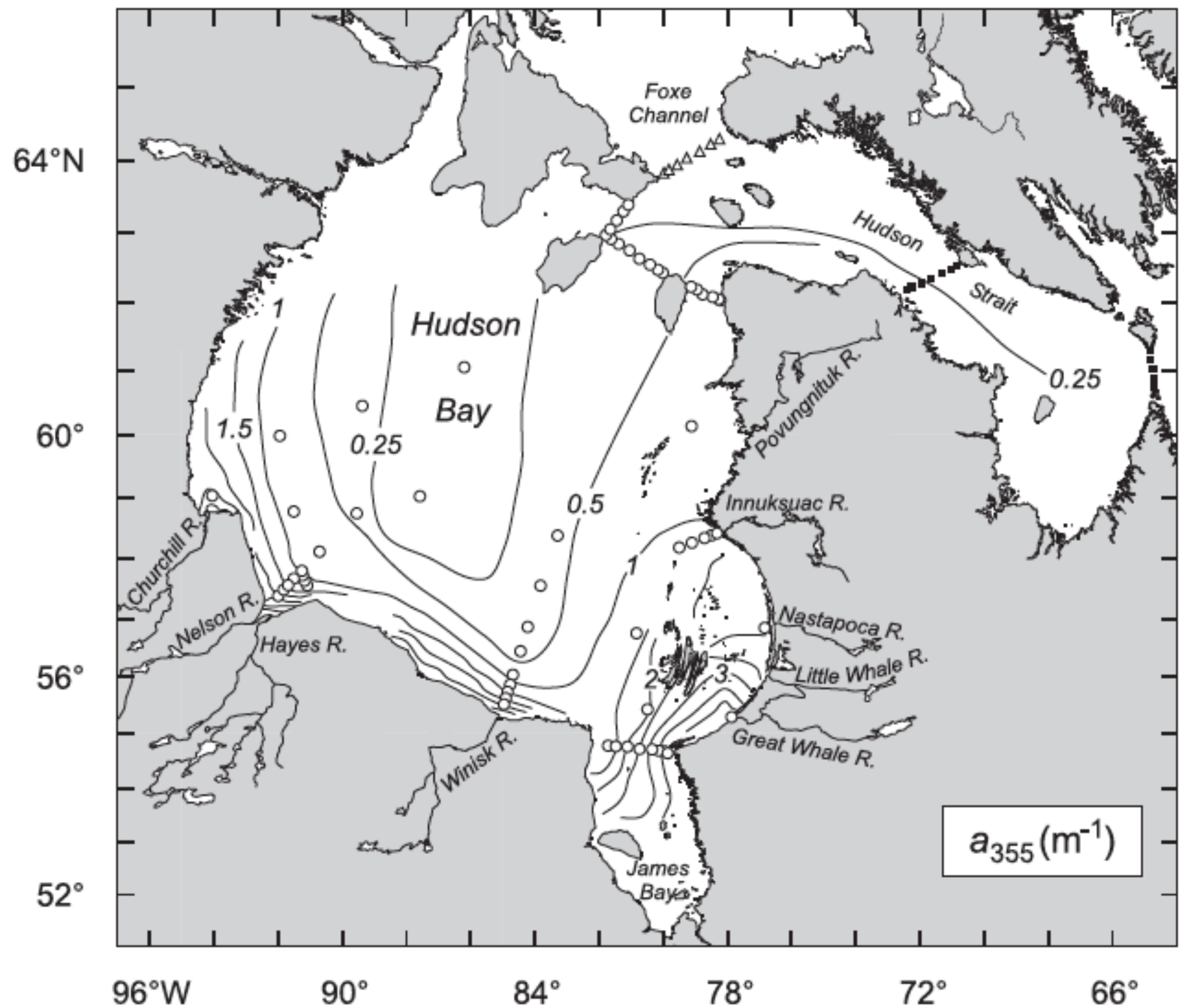
Bourgeault-Brunelle et al. (submitted, JGR)

Province	Year Season	Phytoplankton		Inorganic		Dissolved			
		$a_{\phi}(443)$	$a_{\phi}(443)/a_{t-w}(443)$	$a_{na}(443)$	$a_{na}(443)/a_{t-w}(443)$	$a_{cdom}(443)$	$a_{cdom}(443)/a_{t-w}(443)$	n	Chl a^{Fluo} Range
		(m^{-1})	(%)	(m^{-1})	(%)	(m^{-1})	(%)	-	(mg m^{-3})
Amundsen Gulf (this study)	2007 Fall	0.011 (0.005)	11	0.021 (0.021)	21	0.068 (0.040)	68	10	0.1-0.7
Amundsen Gulf (this study)	2008 Spring & summer	0.019 (0.015)	21	0.006 (0.003)	7	0.063 (0.031)	72	20	0.06-0.5
Canadian Arctic Archipelago (this study)	2007 Fall	0.019 (0.008)	21	0.013 (0.04)	14	0.058 (0.015)	65	6	0.3-0.4
Northern Baffin Bay (this study)	2007 Fall	0.031 (0.028)	28	0.013 (0.010)	12	0.067 (0.017)	60	10	0.1-3.0
Hudson Strait -	2005	0.055 (0.013)	65	0.014 ((0.015)	17	0.015 (0.005)	18	2	0.3-0.8
Hudson Bay* (this study)	Fall	0.045 (0.020)	13	0.026 (0.003)	7	0.29 (0.21)	80	13	0.2-1.0
Chukchi Sea, Western Arctic Ocean [*Mastuoka et al.*, 2011] (all depths)	2002 Spring: Summer: Fall:	0.017 0.022 0.016	22 29 18	0.011 0.012 0.006	14 16 9	0.049 0.041 0.066	64 55 73	90 110 179	0.05-10
Coastal waters around Europe [*Babin et al.*, 2003] (surface waters)	1997-1998 Spring, summer & fall	0.005-1.0	36	0.001-1.0	22	0.007-0.7	41	330	0.002-30

Fall mixed layer CDOM (a_{355}) distribution

Granskog et al. (2007)

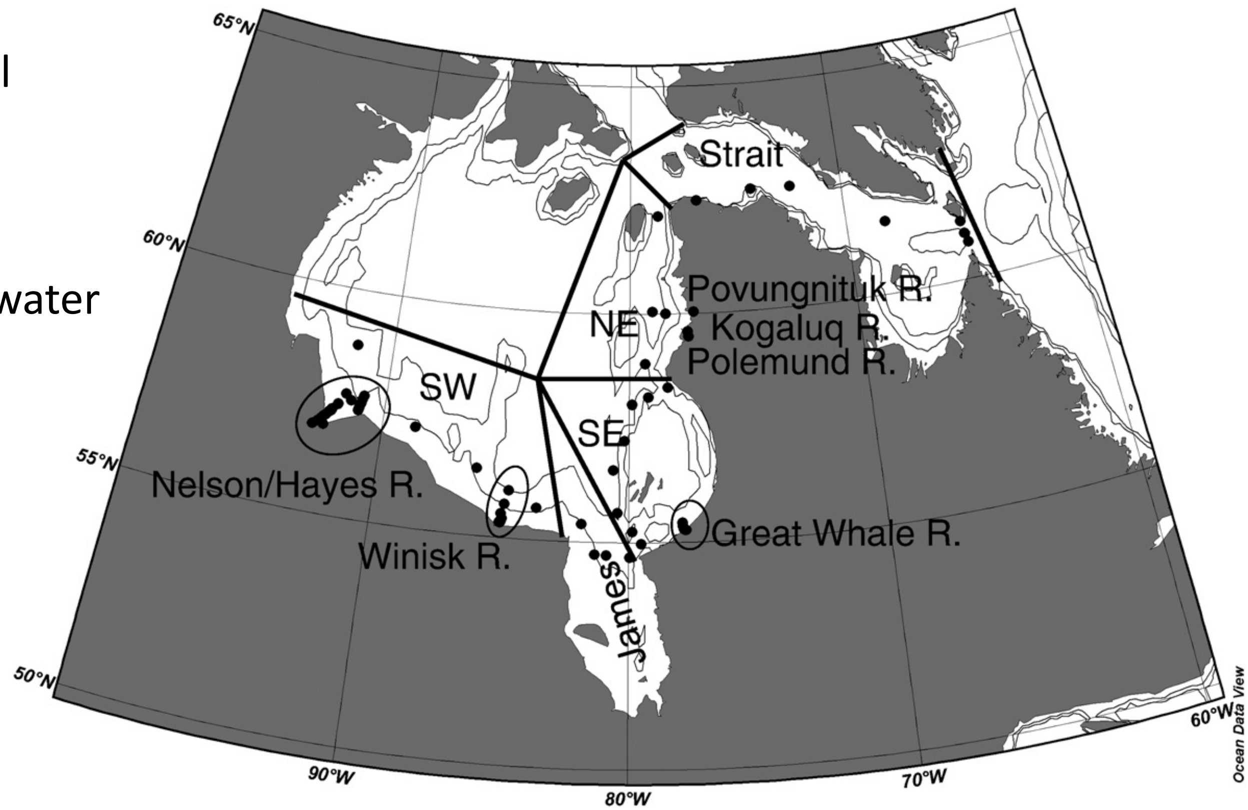
- Terrestrial inputs govern CDOM in HB
- CDOM confined to nearshore
- This has effects on UV penetration
- Photodegradation of CDOM may be a source of nitrates to coastal waters



2007 PARAFAC CDOM analysis

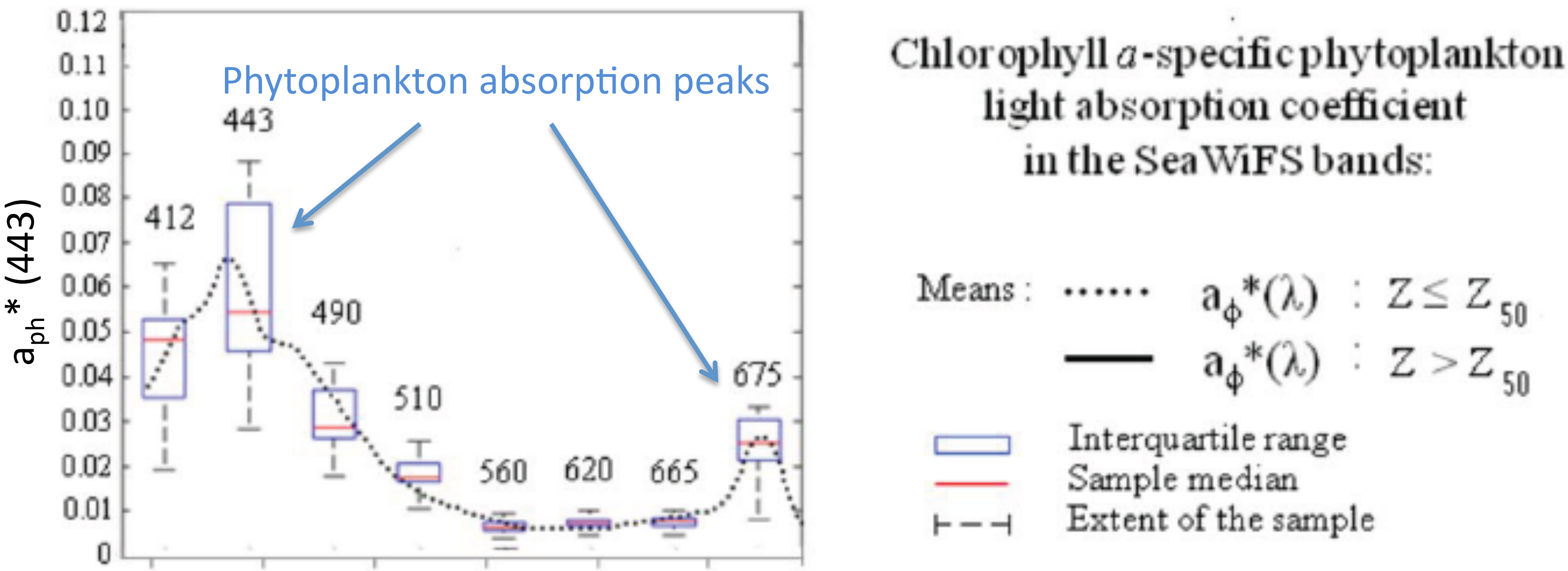
Guegen et al. (2011)

- CDOM has 3 sources:
  - 2 humic (terrestrial +land/marine)
  - 1 protein (marine/ phytoplankton)
- CDOM is controlled by water mass mixing



Phytoplankton absorption

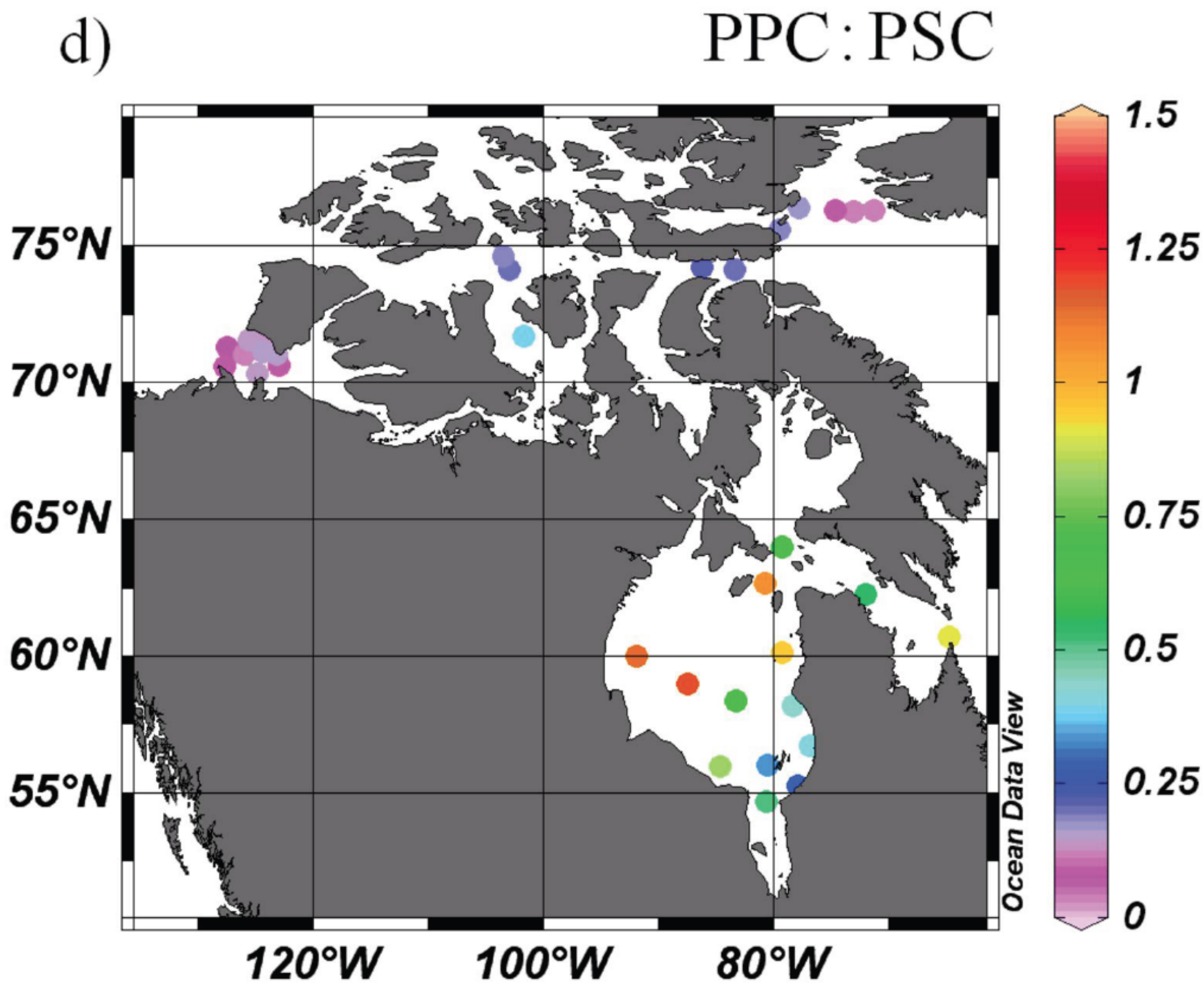
Bourgeault-Brunelle et al. (submitted JGR)



a_{ph}* (443) is relatively high compared to higher latitudes arctic regions

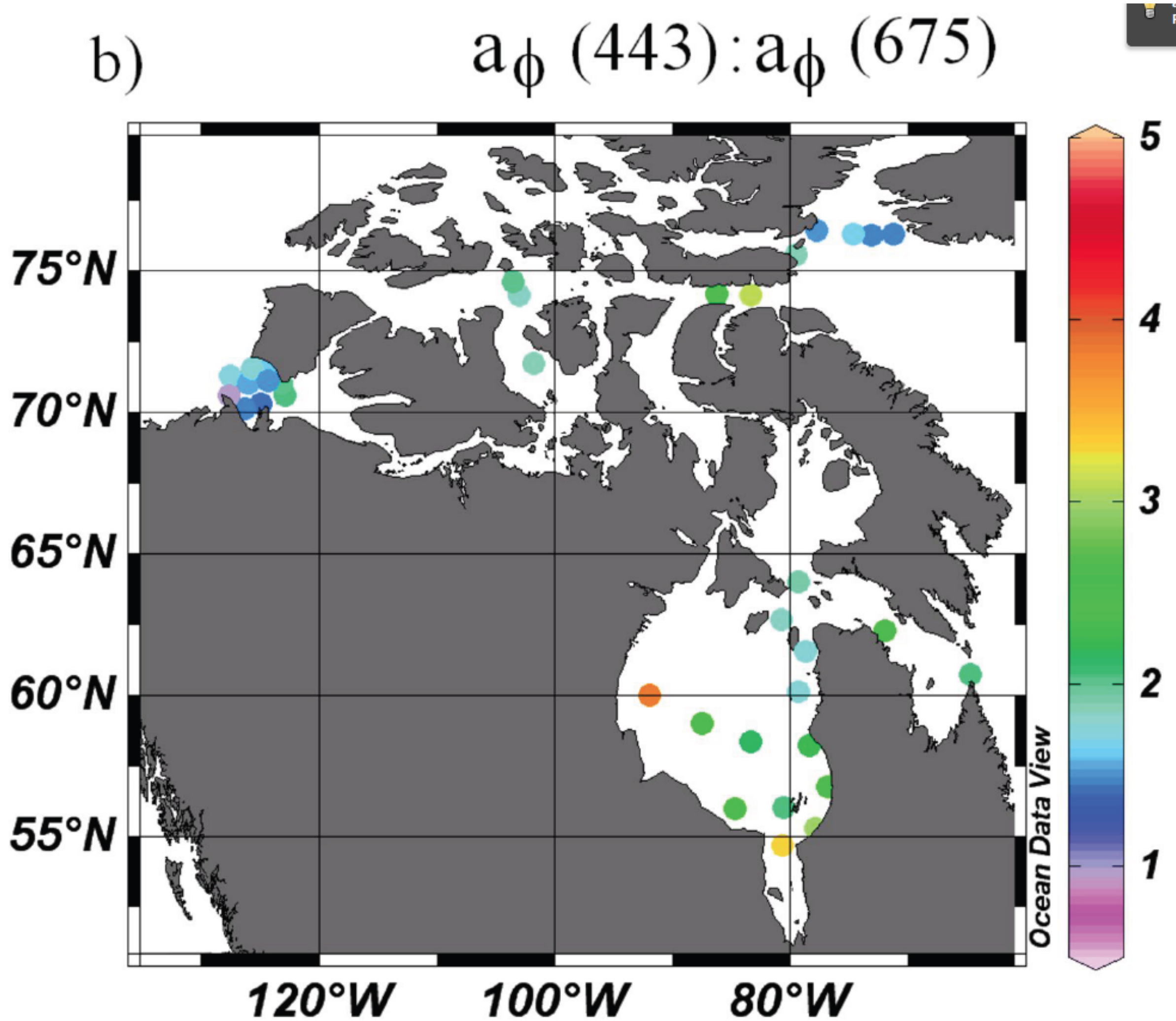
Pigment analysis

- Proportion of PPC is higher in Hudson Bay
- Evident spatial variability



Blue to red ratio

- High blue to red ratio in Hudson Bay
- Spatial variability



Other characteristics of a_{ph}*

- High Q*(675) => low packaging because of the predominance of small cells in Hudson Bay
- Lower pigments per cell in Hudson Bay
- High a_{ph}*(443) related to the higher proportion of PPC in Hudson Bay

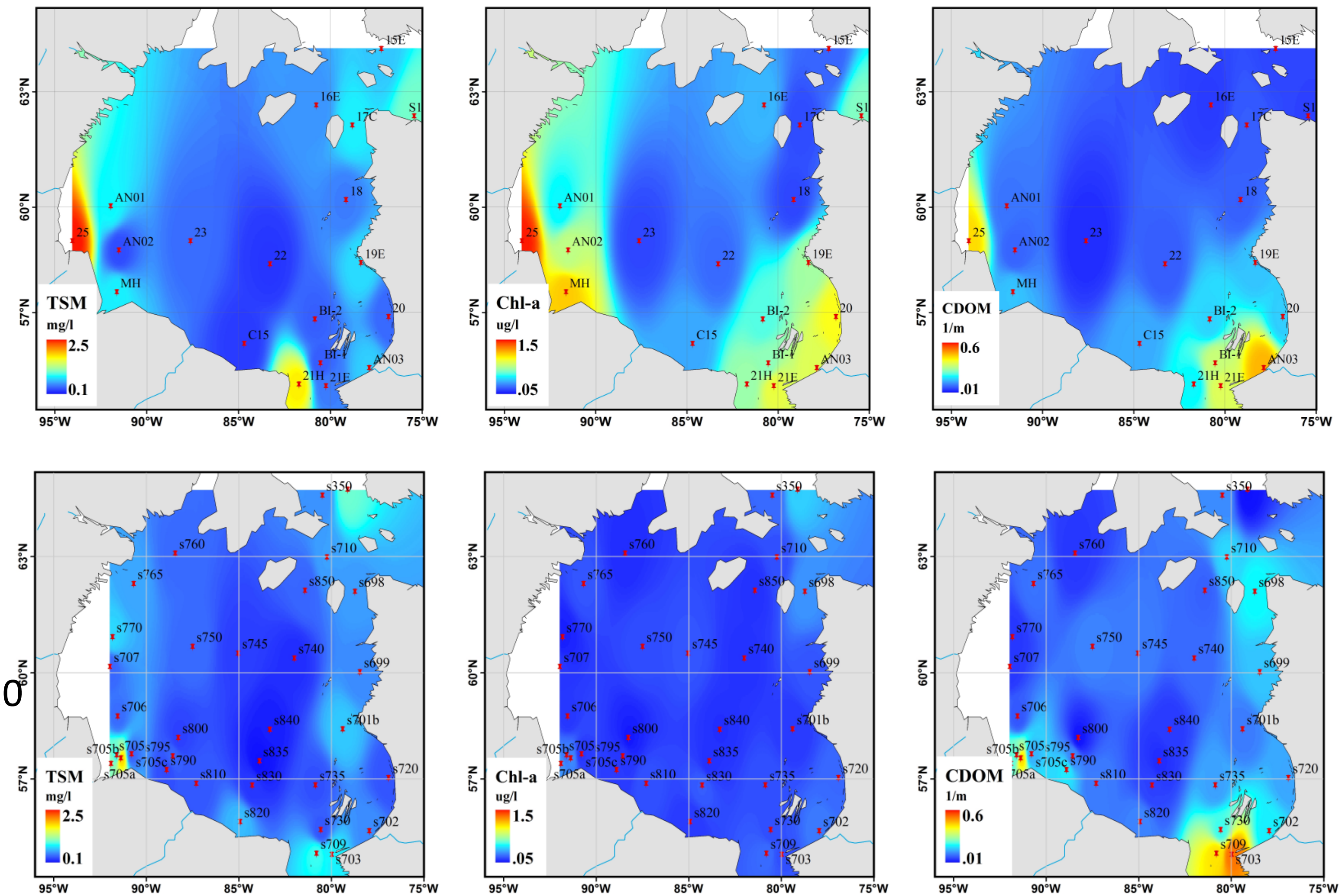
- So Hudson Bay a_{ph}* is very different from other Arctic locations and spatially variable

Seasonal variability

Preliminary results (Xi et al., in prep., see poster)

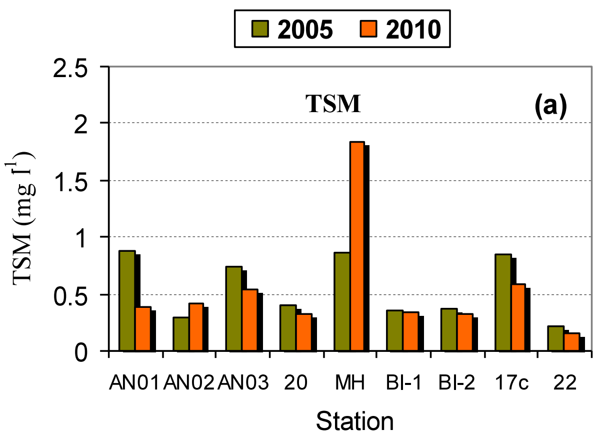
Fall 2005

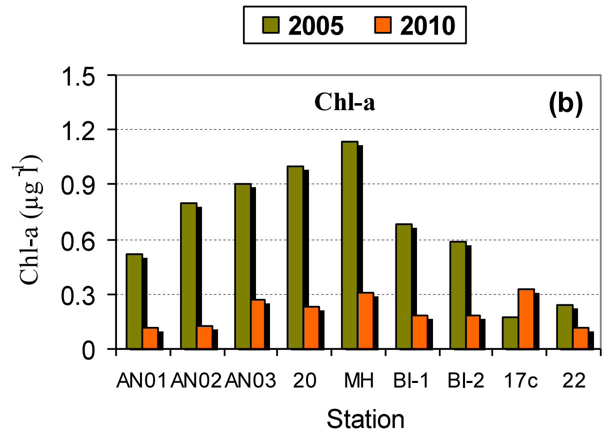
Summer 2010



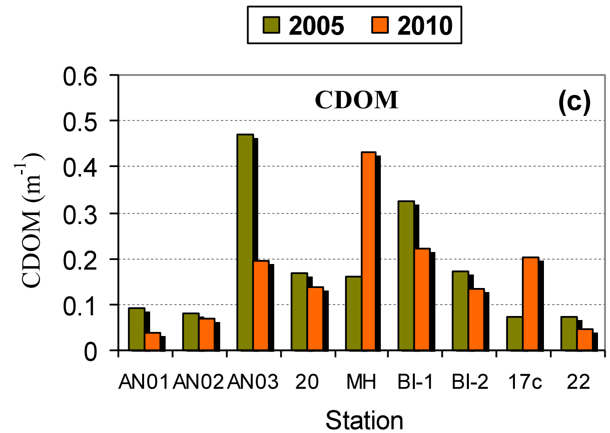
Similar spatial distribution but higher chl*a* and CDOM in fall

Seasonal variability (2)



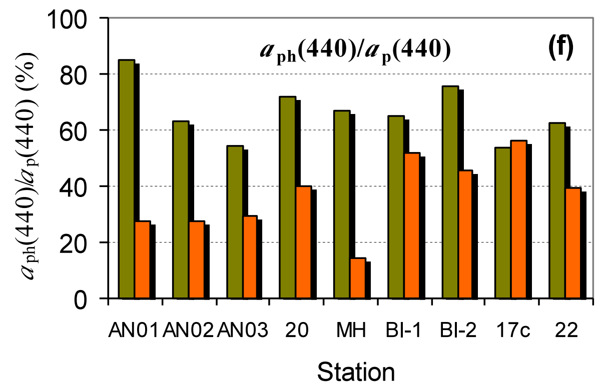


Higher Chl*a* fall



Higher CDOM fall

Orange: summer
Green : fall



Higher a_{ph} fall

a_{cdom}: 93% (80), a_{ph}: 2% (13), a_{na}: 5% (7)

440 nm Summer (fall)

Seasonal variability (3)

- Analysis of 2010 data are not yet completed but:
  - Higher a_{ph}* in the fall
  - Blue/red ratio is similar => similar pigment composition

Summary

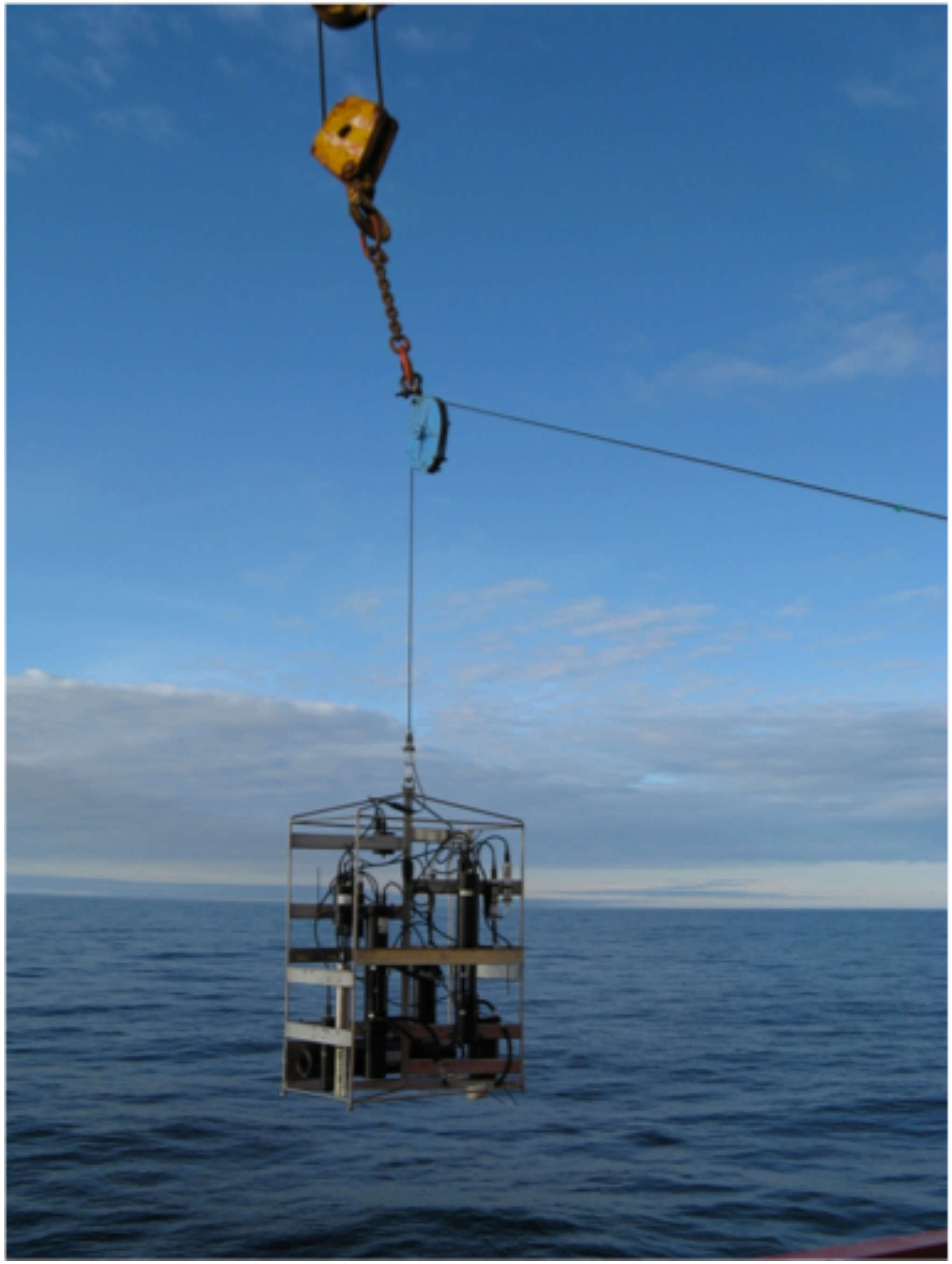
- We know about:
  - Hudson Bay has a relatively low phytoplankton biomass overall
  - We have a good basic knowledge of IOP and WCP spatial distribution
  - There is strong spatial variability of optical properties with some hotspots
  - We know that there is some seasonal variability

The future

- Complete summer/fall comparison
- Address b_b
- Spring transition in relation to stratification and winter nutrient replenishment
- Ice-phytoplankton relationships
- Vertical structure needs to be refined for primary production models
- Phytoplankton photo-protective mechanisms
- Role of CDOM photo-degradation for nitrate supply in coastal regions *vs* mixing sources
- Specificity of Hudson Bay *vs* other nordic inland seas
- James Bay
- Trends (DFO-Aquatic Climate Change Adaptation Services Program)
  - Evolution of Hudson Bay phytoplankton species (from 1953)
  - Biomass evolution (timing and duration using remote sensing)

Conclusion

- Despite major efforts in the past decade, there are still major holes in our scientific knowledge of Hudson Bay optics and their impact on the accurate remote sensing evaluation of important biological parameters.
- This is important for the generation of knowledge about the future evolution of the Bay.
- Continuous efforts must be made to fill these holes.



Thank you